Experience Gained Running PSA Scenarios with MELCOR 2.1

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Contents

Introduction

- MELCOR has been used at NRG since about 1992, when it replaced STCP.
- Over the years MELCOR versions 1.8.2 to 1.8.6 were used.
- In 2011 a PSA level 2 was initiated for Dutch NPP Borssele (KCB)
- Decision was made to use the new MELCOR version, 2.1, for the PSA calculations.
- As a first step, the KCB input deck for MELCOR 1.8.6 was converted manually to 2.1 format.
- Extensions to the existing model were made to provide more detailed modeling, adopt best practicing guidelines and take into account recent modifications of the plant.

Problems Encountered - Input Deck

- Past experience with MELCOR - very good. Compared to STCP and MAAP, very clear description, user friendly input/output structure.

- Specifics of the new MELCOR version:

  - The input format for 2.1 is completely different than for 1.8.6. A large effort is needed to convert the input deck when one does not want to use automatic converter.

  - Input is less flexible. In 1.8.6 input records could be arranged in any order. In 2.1 they must be grouped in sequences for given component.

Problems Encountered - Input Deck

- Consequences:

  - It becomes problematic to use the concept of base-deck and scenario files. One cannot add a valve in scenario input (LOCA!). One must "reserve" dummy valves in the base-deck for the purpose of LOCA, induced ruptures, etc.

  - No additions to the base-deck can be made in scenario file (replacements only). Recombiners are modeled for KCB using mass and energy sources computed by CF/TF. One cannot simply add the recombiner file when needed, because mass/energy sources cannot be added outside base deck. One has to "reserve" dummy mass/energy sources in the appropriate containment CV, to be used when recombiners are active.

  - Results of calculations are dependent on the order in which input deck is arranged.

Problems Encountered - Input Deck

- KCB input consists of about 20 input files.
- We discovered that in some cases changing the order in which files were included resulted in significant differences in results.

- Calculations that were crashing with one sequence, were running fine with another!
- This gives the user a very powerful tool for dealing with code crashes; there is 20!~10^{18} possibilities of arranging the input files for KCB. Some of them must work :)
- For the sake of consistency we decided to use the same (alphabetic) sequence of arranging the files in all scenarios.

```
!
!
!  STANDARD MODEL OF KCB
!  =====================
!
include ..\..\..\Model\Model_21\cav     !  MODEL of: Cavity
include ..\..\..\Model\Model_21\cor     !  MODEL of: Core
include ..\..\..\Model\Model_21\ecs     !  MODEL of: Emergency cooling systems
include ..\..\..\Model\Model_21\press   !  MODEL of: Reactor coolant system
include ..\..\..\Model\Model_21\rcs-1   !  MODEL of: Reactor coolant system
include ..\..\..\Model\Model_21\rcs-2   !  MODEL of: Reactor coolant system
include ..\..\..\Model\Model_21\rpv     !  MODEL of: Reactor pressure vessel
include ..\..\..\Model\Model_21\sgs     !  MODEL of: Steam generators
include ..\..\..\Model\Model_21\cnt     !  MODEL of: Containment
include ..\..\..\Model\Model_21\rec     !  MODEL of: Recombiners
include ..\..\..\Model\Model_21\spr     !  MODEL of: containment spray
include ..\..\..\Model\Model_21\vlv-pmp !  MODEL of: valves, pumps
include ..\..\..\Model\Model_21\env     !  MODEL of: Environment
include ..\..\..\Model\Model_21\sens    !  DATA for: Sensitivities
include ..\..\..\Model\Model_21\rad     !  DATA for: Radionuclides
include ..\..\..\Model\Model_21\mtp     !  DATA for: Material properties
include ..\..\..\Model\Model_21\fdi     !  DATA for: Transport process from
include ..\..\..\Model\Model_21\bur     !  DATA for: Burn-up process
include ..\..\..\Model\Model_21\cfs     !  DATA for: Plot control functions
include ..\..\..\Model\Model_21\rnplot  !  DATA for: Plot release fractions
include ..\..\..\Model\Model_21\time    !  DATA for: Time used in Visor
```

Problems Encountered - Input Documentation

- Documentation of 2.1 is much less clear than in 1.8.6. Input entries that had within 1.8.6 a clear number within the record, are now listed in the input without any number.
- For example, in case of mass energy sources, if the user wishes to use droplets, it is unclear which word defines the Sauter diameter ISAUOPT, DIAM, IFOGOPT.

```
!
!   Flashing model activated for source 3, superheated liquid from RPV
!
    5  WM    RATE  CF  'MASS2-H2O-RSUM'          1.0                  ! Source 3: water source into sump from RPV
    6  WE    RATE  CF  'ENTH2-H2O-RSUM' FOG  6.0 CONST 0.001  !CF, IDMAT, ELEV=6.0 m, ISAUOPT, DIAM=1.0 mm
```

What is wrong in the above input and how am I supposed to figure it out from the description?
(MELGEN error message: too many input entries)

note: we had to figure it out by trial and error, checking MEGOUT file

( ) IDMAT
Material name or number for mass source:
(a) 1 or POOL
Pool.
(b) 2 or FOG
Fog.
(c) 3 or H2O-VAP
Atmospheric vapor.
(d) n ≥ 4 or NCG name
A noncondensible gas identified by the input to
package. Note: For TE source only, this
required as a placeholder for the present. TI
from the immediately-preceding mass source
used.
(type = integer/character(8), default = none, units = dime
( ) ELEV
Elevation of the source in the volume.
(type = real, default = none)
( ) ISAUTOPT
Input switch defining Sauter mean diameter of water dro
(a) CONST
Use constant value DIAM.
(b) CF
Use control function CFDIAM.
(c) SC
Use value of sensitivity coefficient C4500(3).

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(type = character*5, default = none)

optionally followed by

( ) DIAM
Constant value for Sauter mean diameter of water droplets.
(type = real, default = 0.0)

or

( ) CFDIAM
Control function name which defines Sauter mean diameter of water droplets.
(type = character*16, default = none)
( ) IFOGOPT
Fog option flag.
(d) =0:
Distribute fog over RN sections directly.
(e) ≠0:
Allow RN to calculate distribution, assuming condensation.
(type = integer, default = 0)

Example

```
CV_SOU    2   !N CTYP INTERP IESSRC CF/TFNAME IDMAT ESSCAL
               1 MASS RATE   CF     CF498     POOL  1.0
               2 TE   RATE   CF     CF499     -1    1.0
```

Problems Encountered - Modeling Issues

- In several cases models that were running fine in 1.8.6, are crashing whenever activated, sometimes already during input processing, in 2.1.
  - We had a problem with reactor cavity. This was reported to SNL in September 2011. The bug was solved by SNL.
  - The HPME model, which was running without a problem in old MELCOR versions, does not pass input processing in 2.1. We decided to skip the HPME calculations. A possible way to overcome this problem would be to analyze HPME event outside the base model, using only the containment model, mass/energy sources, TF/CF.
  - Generally 2.1 is observed to be less numerically stable than 1.8.6. Crashes are quite frequent, diagnostics is difficult to interpret and find solution. Some of these may be overcome by sensitivity coefficients. Frequently observed HS convergence problem, solved by reducing the convergence criteria for HS.

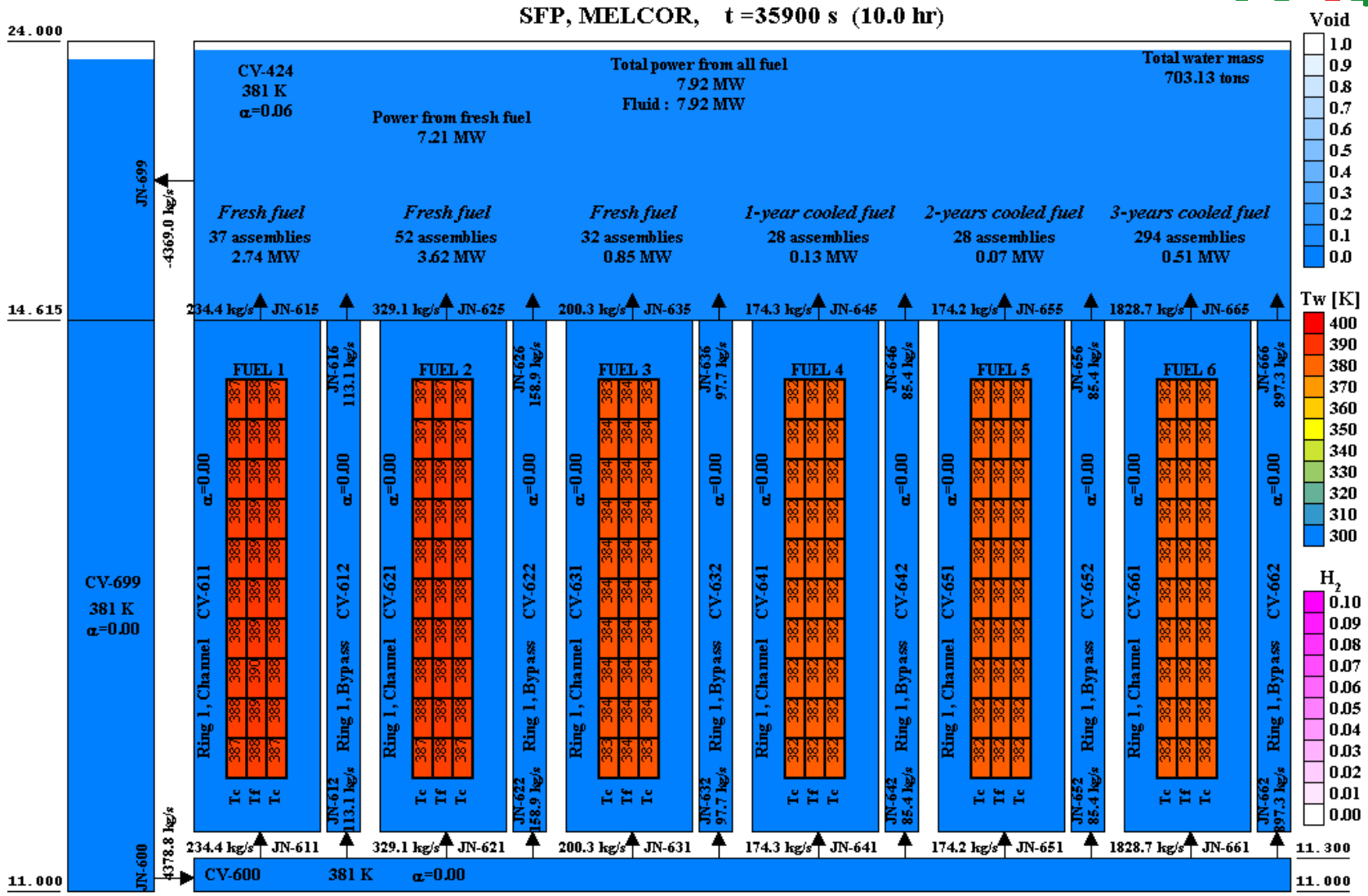
Spent Fuel Pool Model

- Spent Fuel Pool model was created for KCB.

- Fuel in the pool consists of:
  - Fresh fuel (assumed 1 day after SCRAM)
  - 1-year old fuel
  - 2-year old fuel
  - 3-year old fuel

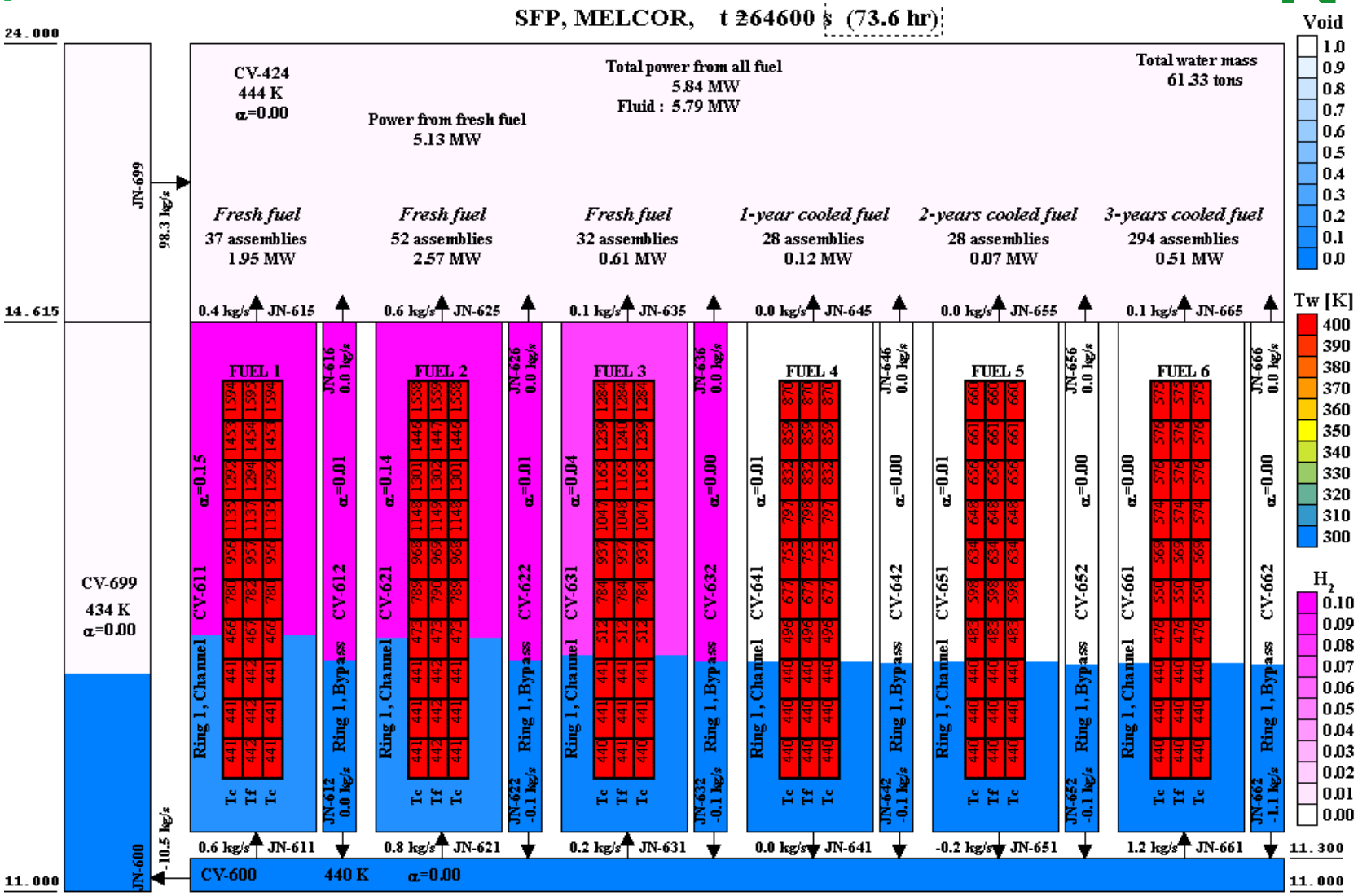
- Model consists of:
  - CVH/FL/COR/RN/CAV/FDI
  - Core Ring 1, 2, 3: fresh fuel
  - Core Ring 4: 1-year old fuel
  - Core Ring 5: 2-year old fuel
  - Core Ring 6: 3-year old fuel

Spent Fuel Pool Model



- KCB, SFP, t = 10.0 hr

Spent Fuel Pool Model



- KCB, SFP, t = 73.6 hr

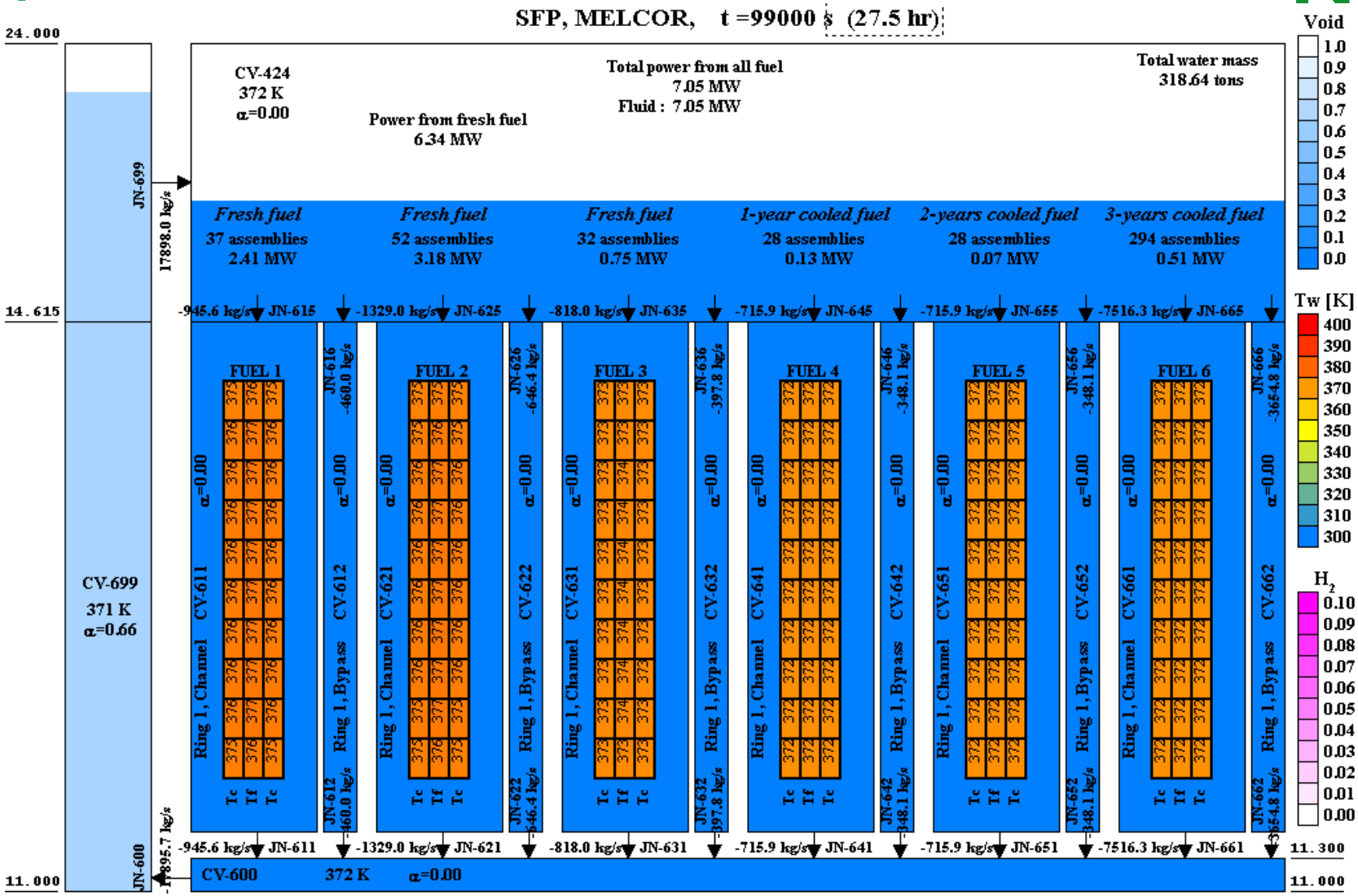
Spent Fuel Pool Model

- Spent Fuel Pool model runs fine, no major problems, except two issues with thermal-hydraulic solution.

  - Void fractions in the fuel channels are limited by default to 0.4. In reality (results of Thermal-Hydraulic system codes) the void fractions increase to 0.8 or even 0.9 in the hottest elements. The is solved by changing the maximum void fraction in CV pool by sensitivity coefficient 4407. MELCOR runs fine with the value of 0.9, results are closer to the TH codes.

  - Reverse circulation in the SFP
    - There is a large containment volume above the pool. It is modeled by a vertical FL with large area, connecting CV-424 with the containment.
    - Reverse natural circulation was observed, with boiling in the volume around the fuel elements - see next slide.
    - Solution: a vertical FL connecting CV-699 with the containment was added. This eliminated the reverse circulation.

Spent Fuel Pool Model



- KCB, SFP, reverse natural circulation

Conclusions

- In contrast to 1.8.6, in 2.1 input deck is not flexible, sensitive to the order in which components are defined. Working with the concept of base-deck and scenario inputs is becoming problematic. Even simplest and most common scenarios, like LOCA, not possible as a set of separate input records added to the base-deck.

- Documentation of 2.1 is much less clear than in 1.8.6. Input entries that had within 1.8.6 a clear number within the record, are now listed in the input without any number.

- In several cases models that were running fine in 1.8.6, are crashing whenever activated, sometimes already during input processing, in 2.1.

- KCB Spent Fuel Pool model runs fine, no major problems, except one small issue with thermal-hydraulic solution.